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Structure-Property Relationships in Biomineralized and Bio-mimetic Composites

Current world technologies and environments rely in large measure upon a growing need for the development of new structural materials with high strength and durability, toughness, light weight, low cost, and complete recyclability. Such materials may be derived synthetically, but Nature has evolved efficient strategies, exemplified in the mineralized tissues of numerous species, that have led to low-weight structural materials that exhibit exceptional strength, durability, and other unique and important properties. In these biomineralized systems, minerals and proteins or additional molecules exist in close proximity and at a various length scales, through their hierarchical structure from nano- to microscale dimensions. Interactions at these inorganic-organic interfaces are vital to the functions of a great variety of structural materials and biological tissues found in the biosphere, including, for example, the shells of mollusks and the bones and teeth of vertebrates.

An active and constantly growing area of research explores the structure-mechanical property relationships of these biomineralized composites with the intention of applying this body of knowledge to the study and mimicry of biomimetic composite materials that can play key roles in developing new materials and structures. The resulting materials will offer a new combination of low weight, high strength/toughness and multifunctionality to break traditional engineering paradigms in a radical manner, and they could benefit a wide spectrum of applications including those related to the automotive industry, energy, shipbuilding, defense, and civil and aerospace engineering. Moreover, studies of biological materials, such as bones and teeth, are also of great importance in the health care arena. The development of biomaterials and tissue-engineered materials is crucial for those instances in which tissues and biological materials need to be replaced, repaired or regenerated because of congenital defects of individuals, injury and other forms of external/internal damage, or disease.

The characterization and study of these materials require the use of modern tools such as electron and scanning probe microscopy, small-scale mechanical testing capabilities, and advanced multiscale numerical models and simulation techniques. At the same time, these investigations are best accomplished through multidisciplinary approaches and so require the close collaboration among material scientists, chemists, physicist, mechanics, bioengineers, clinicians and biologists. The main purpose of Symposium KK held at the 2009 MRS Spring Meeting was to bring together hundreds of scientists and researchers working in the diverse and interdisciplinary areas of biomineralized and biomimetic composite materials. Over 90 oral and poster presentations were given over a period of four days, including those by 20 internationally recognized invited speakers from academia, national laboratories, industries, government, and international institutions. The topics discussed included modeling and simulation of mechanical properties in biomineralized and mimetic systems, experimental design, synthesis and properties in biomineralized and mimetic systems, experimental design, synthesis and properties of biomimetic composites, structure-function properties of biomineralized tissues, biomaterials for tissue engineering, investigation of biomineralized tissue ultrastructure (inorganic and organic), quantitation of the ultrastructural response of the organic and inorganic phases in biological composites to mechanical stresses, and use of high resolution *in situ* synchrotron and spectroscopic techniques. These specific subjects were categorized and detailed in ten sessions, each demonstrating

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the interdisciplinary and distinctive nature of this interesting and significant area of research. A collection of several representative papers is included in the Proceedings Volume 1187.

The organizers acknowledge that the success of Symposium KK depended critically on the full participation of excellent researchers and scientists as well as graduate students. The organizers are also extremely grateful to MRS for making this Symposium possible through its dedicated work before, during and following the Meeting and to the volunteer students who kindly assisted with audio and video help during the sessions. We also thank Gatan UK, the Journal of Materials Chemistry, Nanoforce Technology, Ltd, the Office of Naval Research and the U.S. Department of Energy for their generous and substantial financial support.



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Symposium KK: Structure-Property Relationships in Biomineralized and Biomimetic Composites

Structure-Property Relationships in Biomineralized and Biomimetic Composites
April 14 - 17, 2009

Chairs

David Kisailus	University of California-Riverside
Lara Estroff	Cornell University
William Landis	Northeastern Ohio Universities College of Medicine
Pablo Zavattieri	GM Research & Development Center
Himadri S. Gupta	Queen Mary University of London



Symposium Support

Gatan UK
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Nanoforce Technology Ltd
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* Invited paper

SESSION KK1: Structure-Function Relationships in Biomineralized Tissues I

Chairs: David Kisailus and Eli Sone
Tuesday Morning, April 14, 2009
Room 3024 (Moscone West)

8:30 AM *KK1.1

Brachiopod Shells Control the Material Properties of Calcite. Maggie Cusack¹, Alberto Perez-Huerta¹ and Wenzhong Zhu²;
¹Geographical & Earth Sciences, University of Glasgow, Glasgow, United Kingdom; ²Scottish Centre for Nanotechnology in Construction Materials, University of the West of Scotland, Paisley, United Kingdom.

9:00 AM KK1.2

Abstract Withdrawn

9:15 AM KK1.3

Nacre Evolution : A Proteomic Approach. Benjamin Marie¹, Gilles Luquet¹, Arul Marie², Lionel Dubost², Millet Christian³, Laurent Bedouet³, Michel Becchi⁴, Isabelle Zanella-Cleon⁴ and Frédéric Marin¹; ¹Umr 5561 Biogeosciences, University of Burgundy, Dijon, Burgundy, France; ²Département RDDM, MNHN, Paris, France; ³UMR CNRS 5178, BOME, MNHN, Paris, France; ⁴UMR 5086 CNRS, IBCP, Lyon, France.

9:30 AM KK1.4

Phenomenon of Multiphase Biomineralization: Silica-Chitin-Aragonite and Silica-Calcite Biocomposites Within Skeletal Formations of Marine Sponges. Hermann Ehrlich and Eike Brunner; Institute of Bioanalytical Chemistry, Dresden University of Technology, Dresden, Germany.

9:45 AM KK1.5

Mechanical Function of a Complex Three-dimensional Suture Joining the Bony Elements in the Shell of the Red-eared Slider Turtle. Ron Shahar¹, Stefanie Krauss², Efrat Monsonogo³ and Peter Fratzl²; ¹Koret school of Veterinary Medicine, The Hebrew University of Jerusalem, Rehovot, Israel; ²Department of Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; ³Institute of Biochemistry and Nutrition, The Hebrew University of Jerusalem, Rehovot, Israel.

10:00 AM BREAK

10:30 AM *KK1.6

Glass in Sponges. Joanna Aizenberg¹, Peter Fratzl² and James C Weaver³; ¹Harvard University, Cambridge, Massachusetts; ²MPI, Golm, Germany; ³UC Riverside, Riverside, California.

11:00 AM KK1.7

Functional Biomimetics - Structure-Property Correlations in Hybrid Biological Tissues Mehmet Sankaya^{1,2}, Hanson Fong^{1,2,4}, Malcolm L Snead^{4,1} and Martha Somerman³; ¹Genetically Engineered Materials Science and Engineering Center, University of Washington, Seattle, Washington; ²Materials Science and Engineering, University of Washington, Seattle, Washington; ³Dental School, University of Washington, Seattle, Washington; ⁴Craniofacial Molecular Genetics, University of Southern California, Los Angeles, California.

11:15 AM KK1.8

High Performance Impact-Tolerant and Abrasion-Resistant Materials: Lessons From Nature James C Weaver¹, Anthony Tantuccio^{3,1}, Jie Lian², Sabrina Louie¹, Junlan Wang² and David Kisailus¹; ¹Chemical and Environmental Engineering, UC Riverside, Riverside, California; ²Mechanical Engineering, UC Riverside, Riverside, California; ³Chemical Engineering, The Cooper Union for the Advancement of Science and Art, New York, New York.

11:30 AM KK1.9

Effect of Alport Syndrome Mutations in Tropocollagen on Molecular and Microfibrillar Mechanical Properties. Maya Srinivasan^{1,2}, Sinan Keten², Alfonso Gautier^{3,2} and Markus J Buehler²; ¹Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey; ²Laboratory for Atomistic and Molecular Mechanics, Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts; ³Cellular and Molecular Biomechanics Research Group, Department of Bioengineering, Politecnico di Milano, Milan, Italy.

11:45 AM KK1.10

Influence of Scaffold Composition on Gene Expression and Cellular Organization in Tissue-engineered Middle Phalanx Models of Human Digits. William Joel Landis¹, Yoshitaka Wada^{1,2}, Robin Jacquet¹, Elizabeth Lowder¹ and Noritaka Isogai^{2,1}; ¹Integrative Medical Sciences, Northeastern Ohio Universities Colleges of Medicine and Pharmacy, Rootstown, Ohio; ²Plastic and Reconstructive Surgery, Kinki University Medical School, Osaka, Japan.

SESSION KK2: Structure-Function Relationships in Biomineralized Tissues II
Chairs: Lara Estroff and Christine Orme
Tuesday Afternoon, April 14, 2009
Room 3024 (Moscone West)

1:30 PM *KK2.1

Alternative to DOPA in a Mussel Adhesive Protein. Herbert Waite, Marine Science Institute, UCSB, Santa Barbara, California.

2:00 PM *KK2.2

Plant Actuation by the Swelling of Cellulose Nanocomposite Architectures. Peter Fratzl and Ingo Burgert; Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Germany.

2:30 PM KK2.3

Adhesive Structure of the Freshwater Zebra Mussel, *Dreissena polymorpha*. Nikrooz Farsad¹, Trevor W Gilbert² and Eli D Sone^{1,2,3}; ¹Materials Science & Engineering, University of Toronto, Toronto, Ontario, Canada; ²Institute of Biomaterials & Biomedical Engineering, University of Toronto, Toronto, Ontario, Canada; ³Faculty of Dentistry, University of Toronto, Toronto, Ontario, Canada.

2:45 PM KK2.4

Nano-Porous Sucker Rings from *Dosidicus gigas*. Miserez Ali^{2,3}, James C Weaver⁴, Peter B Pedersen¹, Todd Schneeberk², Roger Hanlon⁵, David Kisailus⁴ and Henrik Birkedal¹; ¹Department of Chemistry & Interdisciplinary Nanoscience Center, Aarhus University, Aarhus, Denmark; ²Department of Molecular, Cellular, and Developmental Biology, University of California, Santa Barbara, Santa Barbara, California; ³Materials Department, University of California, Santa Barbara, Santa Barbara, California; ⁴Department of Chemical and Environmental Engineering, University of California, Riverside, Riverside, California; ⁵Marine Biological Laboratory, Woods Hole, Massachusetts.

3:00 PM BREAK

3:30 PM *KK2.5

In-vitro Mechanical Testing of Single Collagen Nanofibrils Steven Eppell¹, Zhilei Liu Shen¹, Reza Daj¹, Harold Kahn² and Roberto Ballarini³; ¹Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio; ²Materials Science and Engineering, Case Western Reserve University, Cleveland, Ohio; ³Civil Engineering, University of Minnesota, Minneapolis, Minnesota.

4:00 PM *KK2.6

Cement Lines and Bone Quality - A Lesson from Studies of Long-lasting Cement Lines in Osteopetrotic Bones of Aging c-src Deficient Mice. Yoshiro Takano, Biostructural Science, Dept. of Hard Tissue Engineering, Tokyo Medical and Dental School, Tokyo, Japan.

4:30 PM KK2.7

Unravelling Pathways for Functional Remineralization of Dentin. Luiz Eduardo Bertassoni, Stefan Habelitz, Megan Pugach, Sally J Marshall and Grayson W Marshall; Preventive and Restorative Dental Sciences, UCSF, San Francisco, California.

4:45 PM KK2.8

Damage and Crack Evolution in Mammalian Enamel James Jin-Wu Lee^{1,2}, Brian R Lawn¹, Paul Constantino² and Peter Lucas²; ¹Ceramics Division, National Institute of Standards and Technology, Gaithersburg, Maryland; ²George Washington University, Washington, District of Columbia.

SESSION KK3: Structure-Property Relationships in Biomimetic Composites I

Chairs: Laurie Gower and Pablo Zavattieri

Wednesday Morning, April 15, 2009

Room 3024 (Moscone West)

8:30 AM *KK3.1

Spider Silk as a Novel High Performance Biomimetic Muscle Driven by Humidity. Ingi Agnarsson², Ali Dhinoiwalla¹, Vasav Sahni¹ and Todd Blackledge²; ¹Polymer Science, The University of Akron, Akron, Ohio; ²Integrated Bioscience Program, The University of Akron, Akron, Ohio.

9:00 AM KK3.2

Silk/Silica Biomaterials for Bone Remodeling Aneta Joanna Mieszwaska¹, Carole C Perry² and David L Kaplan¹; ¹Biomedical Engineering, Tufts University, Medford, Massachusetts; ²School of Science and Technology, Nottingham Trent University, Nottingham, United Kingdom.

9:15 AM KK3.3

Genetically Engineered Chimeric silk/ Metal Binding Proteins. Heather Currie¹, Rajesh R Naik², Carole C Perry³ and David L Kaplan¹; ¹Department of Biomedical Engineering, Tufts University, Medford, Massachusetts; ²Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio; ³School of Science and Technology, Nottingham Trent University, Nottingham, United Kingdom.

9:30 AM KK3.4

Effect of CaSiO₃ structure and texture on the in vitro behavior of Human Mesenchymal Stem Cells Nianli Zhang¹, Nita Sahai^{1,3}, Jim Molenda² and William Murphy²; ¹Department of Geology and Geophysics, University of Wisconsin - Madison, Madison, Wisconsin; ²Department of Biomedical Engineering, University of Wisconsin - Madison, Madison, Wisconsin; ³Department of Chemistry, University of Wisconsin - Madison, Madison, Wisconsin.

9:45 AM KK3.5

Modeling the Mechanical Properties of a Soft Matrix in Biological Composites. Markus A. Hartmann and Peter Fratzl; Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany.

10:00 AM BREAK

10:30 AM *KK3.6

Biologically Inspired Strategies for Interfacial Control in Polymer Nanocomposites. Phillip Messersmith, Biomedical Engineering, Northwestern University, Evanston, Illinois.

11:00 AM KK3.7

A New Tool for Determining Intra- versus Inter-fibrillar Mineral Content in Biomimetic Bone Composites. Sang Soo Jee, Taili Thula, Elliot P Douglas and Laurie B. Gower; Materials Science & Engineering, University of Florida, Gainesville, Florida.

11:15 AM KK3.8

Controlled Magnetite Formation by Mimic Peptides from the Mms6 Protein of Magnetotactic Bacteria. Atsushi Arakaki, Fukashi Masuda, Yosuke Amemiya and Tadashi Matsunaga; Life Science and Biotechnology, Tokyo university of Agriculture and Technology, Tokyo, Japan.

11:30 AM KK3.9

Abstract Withdrawn

SESSION KK4: Structure-Property Relationships in Biomimetic Composites II

Chairs: Himadri Gupta and Nico Sommerdijk

Wednesday Afternoon, April 15, 2009

Room 3024 (Moscone West)

1:30 PM *KK4.1

Inorganic Interaction Protein Sequences: Lifetime Members of the Unique "Intrinsically Disordered Protein" Sequence Club. John Spencer Evans, Fairland Amos and Irit Katash; New York University, New York, New York.

2:00 PM *KK4.2

Biologically Inspired Organic-Inorganic Nanocomposites. Ishan Aksay, Chemical Engineering, Princeton University, Princeton, New Jersey.

2:30 PM KK4.3

Single Crystals with Incorporated Polymer Networks: Hierarchical Structures and Improved Mechanical Properties.

Hanying Li¹, Huolin L Xin², David A Muller³ and Lara A Estroff¹; ¹Material Science and Engineering, Cornell University, Ithaca, New York; ²Department of Physics, Cornell University, Ithaca, New York; ³School of Applied and Engineering Physics, Cornell University, Ithaca, New York.

2:45 PM KK4.4

Crystallisation of Calcium Carbonate within Controlled Microenvironments

Yi-Yeoun Kim¹, Chris Stephens², Nicola B Hetherington¹, Ana-Paula Ramos¹, Hugo K Christenson² and Fiona C Meldrum¹; ¹Chemistry, University of Bristol, Bristol, United Kingdom; ²Physics, University of Leeds, Leeds, Yorkshire, United Kingdom.

3:00 PM BREAK

3:30 PM *KK4.5

Overview of Biomimetic Composites for Morphing Wing Skins Christopher Henry and Geoff McKnight; Active Materials and Adaptive Structures, HRL Laboratories LLC, Malibu, California.

4:00 PM *KK4.6

Wood and Paper as Materials for the 21st Century. Philip Jones¹ and Theodore H Wegner²; ¹Imerys, Roswell, Georgia;

²Theodore Wegner, USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin.

4:30 PM KK4.7

Mechanical Analysis of Macromodels of Biomimetic Composite Materials using Rapid Prototyping Techniques

Mark Cooper¹, Katherine Frank¹, Phillip Russel¹, Michael Waters¹, Alejandro H Strachan¹ and Pablo D. Zavattieri²; ¹School of Materials Engineering, Purdue University, West Lafayette, Indiana; ²General Motors Research and Development Center, Warren, Michigan.

4:45 PM KK4.8

Structure and Stability of Bio-Inspired Calcite Crystals Studied by X-Ray Techniques

Anna Sophia Schenk¹, Barbara Aichmayer¹, Oskar Paris¹, Helmut Cölfen², Christine Lausser² and Peter Fratzl¹; ¹Department of Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Brandenburg, Germany; ²Department of Colloid Chemistry, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Brandenburg, Germany.

SESSION KK5: Poster Session: Structure-Property Relationships in Biomineralized and Biomimetic Composites

Chairs: Lara Estroff, Himadri Gupta, David Kisailus, William Landis and Pablo Zavattieri

Wednesday Evening, April 15, 2009

8:00 PM

Salon Level (Marriott)

KK5.1

Microstructural and Biochemical Characterization of the Nano-porous Sucker Rings from *Dosidicus gigas*

James C. Weaver¹, Ali Miserez², Peter B Pedersen³, Todd Schneeberk², Roger T Hanlon⁴, Henrik Birkedal³ and David Kisailus¹;

¹Department of Chemical and Environmental Engineering, University of California, Riverside, Riverside, California; ²Materials Department, University of California, Santa Barbara, Santa Barbara, California; ³Department of Chemistry, University of Aarhus, Aarhus, Denmark; ⁴Marine Biological Laboratory, Woods Hole, Massachusetts.

KK5.2

Osteogenesis Imperfecta Mutations In Tropocollagen Protein Domains Lead to Molecular Softening and Reduced Intermolecular Adhesion.

Alfonso Gautieri^{3,2}, Maya Srinivasan^{1,2}, Sinan Keten² and Markus J Buehler²; ¹Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey; ²Laboratory for Atomistic and Molecular Mechanics, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts; ³Cellular and Molecular Biomechanics Research Group, Department of Bioengineering, Politecnico di Milano, Milan, Italy.

KK5.3

Characterization of Crustacyanin A2 Subunit as a Component of the Organic Matrix of the *Cherax quadricarinatus* Gastroliths

Gilles Luquet¹, Nathalie Le Roy¹, Sergio Bucarey², Isabelle Zanella-Cléon³, Michel Becchi³, Maria Soledad Fernandez², Jose Luis Arias², Nathalie Guichard¹, Benjamin Marie¹ and Frédéric Marin¹; ¹UMR 5561 CNRS-Université de Bourgogne, Laboratoire de Biogéosciences, Dijon, France; ²Faculty of Veterinary and Animal Sciences, University of Chile, and Centre for Advanced Interdisciplinary Research in Materials (CIMAT), Santiago, Chile; ³Institut de Biologie et Chimie des Protéines, UMR 5086 CNRS-Université Lyon 1, Laboratoire de Spectrométrie de Masse, Lyon, France.

KK5.4

Mechanical Properties and Surface Characterization of Calcium Carbonate Platelet Extracted from Freshwater Pearl Shell.

Xinqi Chen, NUANCE Center, Northwestern University, Evanston, Illinois.

KK5.5

Extreme Mechanical Anisotropy in Bone at the Mesoscale.

Jong Seto¹, Himadri S. Gupta³, Paul Zaslansky¹, H. D Wagner² and Peter Fratzl¹; ¹Department of Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; ²Materials and Interfaces, Weizmann Institute of Science, Rehovot, Israel, ³Queen Mary University of London, School of Engineering and

Materials Science, London, United Kingdom.

KK5.6

Effects of fetuin-A Deficiency on the Material Bone. Jong Seto¹, Himadri S Gupta³, Stefanie Krauss¹, John Dunlop¹, Admir Masic¹, Willi Jahnke-Dechent² and Peter Fratzl¹; ¹Department of Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; ²Biomedical Engineering, Biointerface Group, RWTH Aachen University, Aachen, Germany; ³Queen Mary University of London, School of Engineering and Materials Science, London, United Kingdom.

KK5.7

Abstract Withdrawn

KK5.8

In Vitro Human Osteoblast Responses to Titanium Oxide-Based Surfaces with Varying Topology and Composition. Charles Andrew Collier¹, Helen J Griffiths¹, Athina E Markaki², James A Curran¹ and T. W Clyne¹; ¹Materials Science and Metallurgy, University of Cambridge, Cambridge, Cambridgeshire, United Kingdom; ²Department of Engineering, University of Cambridge, Cambridge, Cambridgeshire, United Kingdom.

KK5.9

Phases, Composition and Microstrain in the Mineralized Byssus of Anomia. Henrik Birkedal and Jakob R Eltzholtz; Department of Chemistry & Interdisciplinary Nanoscience Center, Aarhus University, Aarhus, Denmark.

KK5.10

Shell Recovery Process in the Clam Ruditapes Philippinarum, Affected by the Brown Ring Disease (BRD): a Biochemical Study. Nolwenn Trinklér¹, Frederic Marin², Nathalie Guichard², Maylis Labonne¹, Christine Paillard¹ and Jean-Francois Bardeau²; ¹LEMAR UMR CNRS 6539, IUEM UBO, Plouzané, France; ²Laboratoire de Biogéosciences UMR 5561, UB, Dijon, France.

KK5.11

Abstract Withdrawn

KK5.12

Abstract Withdrawn

KK5.13

Novel Dental Restorative Composites having Excellent Mechanical Properties and Reduced Volumetric Shrinkage during Polymerization. Sun H Yoo, You S Chung and Chang Keun Kim; School of Chemical Engineering & Materials Science, Chung-Ang University, Seoul, Korea, South.

KK5.14

Molecular Recognition at the Organo-Mineral Interface between Protein and Bone. Jonathan James Phillips^{1,2} and Seung-Wuk Lee^{1,2}; ¹Bioengineering, UC, Berkeley, Berkeley, California; ²Physical Biosciences, Lawrence Berkeley National Laboratory, Berkeley, California.

KK5.15

Abstract Withdrawn

KK5.16

Nanosilica Formation at Lipid Membranes Induced by Sialfin Peptides. Michael Kent¹, Jaclyn Murton¹, Frank Zendejas², Huu Tran², Blake Simmons², Sushil Satija³ and Ivan Kuzmenko⁴; ¹Sandia National Labs, Albuquerque, New Mexico; ²Sandia National Labs, Livermore, California; ³National Institute of Standards and Technology, Gaithersburg, Maryland; ⁴Argonne National Labs, Argonne, Illinois.

KK5.17

Synthesis Of Porous Calcium Phosphate Nanotubes. Deepa Khushalani, Dept. of Chemical Sciences, TIFR, Mumbai, MH, India.

KK5.18

The Effect of Silk Fibroin Hydrogels, Peptides, and β -chitin on Calcium Carbonate Crystallization: A Synthetic Model for Nacre Formation. Ellen C Keene¹, John S Evans² and Lara A Estroff¹; ¹Material Science & Engineering, Cornell University, Ithaca, New York; ²Laboratory of Chemical Physics, New York University, New York City, New York.

KK5.19

Abstract Withdrawn

KK5.20

Electrical Characterization of Functionalized Diatom Pinnularia sp. Biosilica. Timothy Gutu¹, Clayton Jeffries², Gregory L Rorrer² and Jun Jiao¹; ¹Department of Physics, Portland State University, Portland, Oregon; ²Department of Chemical Engineering, Oregon State University, Corvallis, Oregon.

KK5.21

Numerical Studies and Dimensional Analysis for Designing Bio-Inspired Composite Materials Jee E Rim¹, Pablo D.

Zavattieri² and Horacio D Espinosa¹; ¹Department of Mechanical Engineering, Northwestern University, Evanston, Illinois;
²General Motors Research and Development Center, Warren, Michigan.

KK5.22

Abstract Withdrawn

KK5.23

Composite Biomaterial of Ceramic-polymer: Development and Characterization. Miriam Estevez, Rogelio Rodriguez, Angel M Escamilla and Ana Leonor Rivera; Centro de Física Aplicada y Tecnología Avanzada, Universidad Nacional Autónoma de México, Queretaro, Qro, Queretaro, Mexico.

KK5.24

Coating Electrospun Poly(ϵ -caprolactone) Fibers with Gelatin and Calcium Phosphate for Bone Tissue Engineering Xiaoran Li^{1,2}, Jingwei Xie¹, Xiaoyan Yuan² and Younan Xia¹; ¹Department of Biomedical Engineering, Washington University in St. Louis, St. Louis, Missouri; ²School of Materials Science and Engineering, Tianjin University, Tianjin, China.

KK5.25

Transferred to KK3.4

KK5.26

Self-healable Biopolymers for Drug Delivery and Tissue Engineering Xuanhe Zhao, Nathaniel D Huebsch, David J Mooney and Zhigang Suo; School of Engineering and Applied Science, Harvard University, Cambridge, Massachusetts.

KK5.27

Thermal and Melt Property Characterization of Biodegradable Polyesters for Batch-Foaming. Qi Liao and Curt W Frank; Department of Chemical Engineering, Stanford University, Stanford, California.

KK5.28

Amino- and Carboxy-functionalized Nano- and Microstructured Surfaces for Evaluating the Impact of Non-biological Stimuli on Adhesion, Proliferation and Differentiation of Primary Skin-cells. Petra Kluger², Kirsten Borchers¹, Achim Weber¹, Guenter E Tovar^{1,3} and Heike Mertsching²; ¹Biomimetic Interfaces, Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, Stuttgart, Germany; ²Cell Systems, Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, Stuttgart, Germany; ³Institute for Interfacial Engineering, University of Stuttgart, Stuttgart, Germany.

KK5.29

Synthesis and Characterization of Novel Biodegradable and Injectable Hydrogels for Tissue Engineering based on PLA-PEG-PLA Block Copolymers. Kevin W. Worrell and Karl I Jacob; Polymer, Textile & Fiber Engineering, Georgia Institute of Technology, Atlanta, Georgia.

KK5.30

P(L,L-lactide) / pseudowollastonite-based Composites : New Biomimetic Materials for Bone Regeneration. Deborah ThÄ©rÄ©se-JosÄ©phine Barone¹, Pascal Viville², Jean-Marie Raquez¹, Alexandra Belayew³, Roberto Lazzaroni² and Philippe Dubois¹; ¹Laboratory of Polymeric and Composite Materials, University of Mons-Hainaut, Mons, Belgium; ²Laboratory for Chemistry of Novel Materials, University of Mons-Hainaut, Mons, Belgium; ³Laboratory of Molecular Biology, University of Mons-Hainaut, Mons, Belgium.

KK5.31

Enhancement of Osteoclastic Differentiation of Mouse Bone Marrow Cells Cultured on Hydroxyapatite/collagen Bone-like Nanocomposite. Masanori Kikuchi¹ and Atsushi Irie²; ¹Biomaterials Center, National Institute for Materials Science, Tsukuba, Japan; ²Biomembrane Signaling Project, Tokyo Metropolitan Institute of Medical Science, Tokyo, Japan.

KK5.32

Digital Image Correlation shows Localized Deformation Bands in Inelastic Tensile Loading of Fibrolamellar Bone. Michael Kerschnitzki¹, Gunthard Benecke¹, Peter Fratzl¹ and Himadri S Gupta²; ¹Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Brandenburg, Germany; ²School of Engineering and Materials Science, Queen Mary, University of London, London, United Kingdom.

KK5.33

Abstract Withdrawn

KK5.34

In vitro Studies of DSS-8 Peptide on Nano-mechanical Behaviors for Remineralized Human Dentin Chia-Chan Hsu¹, Hsiu-Ying Chung¹, Elizabeth Marie Hagerman², Jenn - Ming Yang¹ and Benjamin M Wu^{1,2}; ¹Materials Science and Engineering, UCLA, Los Angeles, California; ²Department of Bioengineering, UCLA, Los Angeles, California.

KK5.35

Microstructural Investigation of Creep and Fatigue Properties of Cortical Bone. Claudia Fleck, Materials Engineering, Technical University of Berlin, Berlin, Germany.

KK5.36

The Substrate Effect on the Cell Properties from Indentation Measurement. Guoxin Cao and Names Chandra; university of

Nebraska-Lincoln, Lincoln, Nebraska.

KK5.37

Abstract Withdrawn

KK5.38

Indentation and Uniaxial Compression Study of Enamel's Elastic/plastic Behavior from Nanometer to Millimeter Length Scale. Siang Fung Ang¹, Stefan Habelitz², Amdt Klocke^{3,4}, Mike Swain^{5,6} and Gerold A Schneider¹; ¹Institute of Advanced Ceramics, Hamburg University of Technology, Hamburg, Germany; ²Division of Biomaterials and Bioengineering, Department of Preventive and Restorative Dental Sciences, University of California, San Francisco, San Francisco, California; ³Division of Orthodontics, Department of Orofacial Sciences, University of California, San Francisco, San Francisco, California; ⁴Department of Orthodontics, University Medical Center Hamburg-Eppendorf, Hamburg, Germany; ⁵Faculty of Dentistry, The University of Sydney, Sydney, New South Wales, Australia; ⁶University of Otago, Dunedin, Otago, New Zealand.

KK5.39

Modeling the Elastic and Creep Properties of Collagen Fibril. Fang Yuan¹, Anjali Singhal¹, L. C Brinson^{2,1}, David C Dunand¹, Jonathan D Almer³ and Dean R Haeflner³; ¹Materials Science and Engineering, Northwestern University, Evanston, Illinois; ²Mechanical Engineering, Northwestern University, Evanston, Illinois; ³Advanced Photon Source, Argonne National Laboratory, Argonne, Illinois.

KK5.40

Structure and Mechanical Properties of Horn Keratin. Ekaterina Evdokimenko¹, Luca Tombolato¹, Jerry Curiel¹, Po-Yu Chen² and Joanna McKittrick^{2,1}; ¹Mechanical and Aerospace Engineering, University of California, San Diego, La Jolla, California; ²Materials Science and Engineering, University of California, San Diego, La Jolla, California.

KK5.41

Exploring Nucleation in Biomimetic Systems Through In Situ, Fluid Cell TEM. Michael H Nielsen^{1,2}, Jonathan R Lee² and James J De Yoreo¹; ¹Lawrence Berkeley Lab, Berkeley, California; ²Lawrence Livermore National Lab, Livermore, California.

SESSION KK6: Reversible Deformation and Fracture Mechanics of Biological Composites I
Chairs: Himadri Gupta and William Landis
Thursday Morning, April 16, 2009
Room 3024 (Moscone West)

8:30 AM *KK6.1

Phosphorylated Proteins May Play a Significant Role in the Fracture Resistance of Bone. Paul Hansma, University of California, Santa Barbara, California.

9:00 AM KK6.2

Statistical Model of the Dynamic Mechanical Response of Nacre. Mark H. Jhon^{1,2} and Daryl C Chrzan^{1,2}; ¹Department of Materials Science and Engineering, University of California, Berkeley, Berkeley, California; ²Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California.

9:15 AM KK6.3

The Structural and Mechanical Design of Interfaces in Palms and Reeds. Markus Rueggeberg^{1,2}, Thomas Speck² and Ingo Burgert¹; ¹Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; ²Botanic Garden, Faculty of Biology, University of Freiburg, Freiburg, Germany.

9:30 AM KK6.4

Nano-/micro-structural Response of the Collagen/matrix Composite In Human Arterial Adventitia Links to Mechanical Properties. Amenitsch Heinz¹, Fernando Cacho-Nerin¹, Fabian Schmid¹, Barbara Sartori¹, Michael Rappolt¹, Gerhard A Holzapfel² and Peter Laggner¹; ¹Institute of Biophysics and Nanosystems Research, Austrian Academy of Sciences, Graz, Austria; ²Institute for Biomechanics, Graz University of Technology, Graz, Austria.

9:45 AM KK6.5

AFM and PFM measurements of Enamel in order to Determine the Crack Tip Toughness and Cohesive Zone of Enamel Gerold A Schneider, Siang Fung Ang and Rodrigo Pacher Fernandes; Institute of Advanced Ceramics, Hamburg University of Technology, Hamburg, Germany.

10:00 AM BREAK

10:30 AM *KK6.6

Probing Nanomechanical Behavior of Biological Fibrous Materials using Combination AFM-SEM. Asa H Barber, Fei Hang and Dun Lu; Department of Materials, Queen Mary, University of London, London, United Kingdom.

11:00 AM KK6.7

Transferred to *KK9.1

11:15 AM KK6.8

Unique Structural Designs Leading to the Inelastic Deformation of Haversian Bone. Vincent Ebacher and Rizhi Wang;

Materials Engineering, University of British Columbia, Vancouver, British Columbia, Canada.

11:30 AM KK6.9

Quasi-static and Dynamic Fracture Behavior of Elk Antler and Bovine Femur Bone. Po-Yu Chen¹, Robb M. Kulin¹, Fengchun Jiang², Jerry Curiel², Fred A Sheppard², Kenneth S. Vecchio^{1,3} and Joanna McKittrick^{1,2}; ¹Materials Science and Engineering, University of California, San Diego, La Jolla, California; ²Mechanical and Aerospace Engineering, University of California, San Diego, La Jolla, California; ³Nanoengineering, University of California, San Diego, La Jolla, California.

11:45 AM KK6.10

The Effect of Organic and Inorganic Modifiers on Hydroxyapatite Dissolution Studied by Atomic Force Microscopy Ki-Young Kwon^{1,2}, Eddie Wang^{1,2} and Seung-Wuk Lee^{1,2}; ¹Physical Biosciences Division, Lawrence Berkeley National Laboratory, Berkeley, California; ²Bioengineering, University of California, Berkeley, California.

SESSION KK7: Reversible Deformation and Fracture Mechanics of Biological Composites II

Chair: Rizhi Wang

Thursday Afternoon, April 16, 2009

Room 3024 (Moscone West)

1:30 PM *KK7.1

The Role of the Organic Component in the Mechanical Behavior of Biomineralized Composites. George Mayer, Materials Science & Engineering, U. of Washington, Seattle, Washington.

2:00 PM *KK7.2

3D High-resolution and High-sensitivity X-ray and Neutron Imaging of Wet Dentine in Teeth. Paul Zaslansky, Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Brandenburg, Germany.

2:30 PM KK7.3

High Energy X-ray Diffraction Measurement of Load Transfer between Hydroxyapatite and Collagen in Bovine Dentin Alix Christine Devmier¹, Jonathan D Almer², Dean R Haefner² and David C Dunand¹; ¹Materials Science and Engineering, Northwestern University, Evanston, Illinois; ²Advanced Photon Source, Argonne National Lab, Argonne, Illinois.

2:45 PM KK7.4

Micropillar Compression of Individual Osteoarthritic Bone Trabeculae. Andy Bushby, F. Ahmed and H. S Gupta; Centre for Materials Research, Queen Mary, University of London, London, United Kingdom.

3:00 PM BREAK

SESSION KK8: Structure-Property Relationships in Biomimetic Composites III

Chair: Pablo Zavattieri

Thursday Afternoon, April 16, 2009

Room 3024 (Moscone West)

3:30 PM KK8.1

Does the Incorporation of Calcium or Phosphate Control the Rate of Brushite Mineralization? Jennifer L Giocondi¹, George H Nancollas², Alex A Chernov¹ and Christine Orme¹; ¹LLNL, Livermore, California; ²SUNY, Buffalo, New York.

3:45 PM *KK8.2

Nanoscale Phase Ordering in Polymer-Derived Ceramic Composites. Julin Wan¹, Patrick Malenfant¹, Seth Taylor² and Mohan Manoharan¹; ¹Ceramic and Metallurgy Technologies, GE Global Research Center, Niskayuna, New York; ²Northrop Grumman, Aerospace Research Laboratory, Redondo Beach, California.

SESSION KK9: Biomaterials in Tissue Engineering

Chair: Lara Estroff

Friday Morning, April 17, 2009

Room 3024 (Moscone West)

8:30 AM *KK9.1

Nature-inspired Design of Highly Toughened Materials. Maximilien E Launey¹, Etienne Munch¹, Daan H Alsem^{1,2}, Eduardo Saiz¹, Antoni P Tomsia¹ and Robert O Ritchie^{1,3}; ¹Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California; ²National Center for Electron Microscopy, Lawrence Berkeley National Laboratory, Berkeley, California; ³Department of Materials Science and Engineering, University of California, Berkeley, California.

9:00 AM KK9.2

A New Multilayered Composite Bioceramic for Bone Graft. José I Arias¹, Andrónico Neira-Carrillo², Mehrad Yazdani-Pedram², María S Fernandez² and Jose Luis Arias²; ¹Instituto Ciencias Clinicas Veterinarias, Universidad Austral de Chile, Valdivia, Chile; ²Animal Biology, Universidad de Chile and CIMAT, Santiago, Chile.

9:15 AM KK9.3

Poly(lactic-co-glycolic acid) Nanoparticles Improve the Viability of Liver-derived Cells Encapsulated in a Poly(ethylene

glycol) Hydrogel. Wonjae Lee¹, Nam-joon Cho^{2,3}, Menashe Elazar³, Jeffrey S Glenn³ and Curtis W Frank²; ¹Mechanical Engineering, Stanford University, Stanford, California; ²Chemical Engineering, Stanford University, Stanford, California; ³Medicine, Stanford University, Stanford, California.

9:30 AM KK9.4
Abstract Withdrawn

9:45 AM BREAK

10:15 AM *KK9.5

Self-Assembling Peptide Nanofiber Hydrogels Targeted for Dental Tissue Regeneration. Kerstin M Galler^{1,2,3}, Lorenzo Aulisa¹, Adriana C Cavender², Schmalz Gottfried³, Rena N D'Souza² and Jeffrey D Hartgerink¹; ¹Bioengineering, Rice University, Houston, Texas; ²Biomedical Sciences, Baylor College of Dentistry, Dallas, Texas; ³Restorative Dentistry and Periodontology, University of Regensburg, Regensburg, Germany.

10:45 AM KK9.6

Histological and Mechanical Evaluation of the in vivo Bone-bonding Ability on the K2TiO₂n+1/β-Ti Alloy as a Novel Bioactive Material. Chunxiang Cui¹, Yumin Qi¹, Shuangjin Liu¹, Mingfang Zhang², Xuelian Xue¹ and Nan Huang²; ¹School of Materials Science and Engineering, Hebei University of Technology, Tianjin, Tianjin, China; ²Department of Pathology, Tianjin Medical University, Tianjin, Tianjin, China.

11:00 AM KK9.7

Enamel Matrix Guided Growth of Apatite Vuk Uskokovic¹, Li Zhu², Wu Li² and Stefan Habelitz¹; ¹Department of Preventive and Restorative Dental Sciences, University of California, San Francisco, San Francisco, California; ²Department of Oral and Craniofacial Sciences, University of California, San Francisco, San Francisco, California.

11:15 AM KK9.8

Early Stages of Collagen Mineralization Studied by Cryo-TEM: Starting at the Overlap Region? Fabio Nudelman¹, Paul Bomans¹, Koen Pieterse², Laura Brylka¹, Gijsbertus de With¹ and Nico Sommerdijk¹; ¹Laboratory for Materials and Interface Chemistry and Soft Matter Cryo-TEM Research Unit, Dept. of Chemical Engineering and Chemistry, Eindhoven University of Technology, Eindhoven, Netherlands; ²Biomodeling and Bioinformatics, Department of Biomedical Engineering, Eindhoven University of Technology, Eindhoven, Netherlands.

11:30 AM KK9.9

Structural and Mechanical Properties of the Mineral and Protein Phases in Bone. Po-Yu Chen¹, Damon Toroian², Paul A Price², Fred A Sheppard³ and Joanna McKittrick^{1,3}; ¹Materials Science and Engineering, University of California, San Diego, La Jolla, California; ²Biology, University of California, San Diego, La Jolla, California; ³Mechanical and Aerospace Engineering, University of California, San Diego, La Jolla, California.

SESSION KK10: High Resolution Imaging Techniques for Characterizing Organic-Inorganic Composites

Chairs: David Kisailus and Ulrike Wegst

Friday Afternoon, April 17, 2009

Room 3024 (Moscone West)

1:30 PM *KK10.1

The use of CryoTEM to Study the Early Stages of Biomimetic Mineral Formation. Nico A.J.M. Sommerdijk, Laboratory of Materials and Interface Chemistry, Eindhoven University of Technology, Eindhoven, Netherlands; Soft Matter CryoTEM Research Unit, Eindhoven University of Technology, Eindhoven, Netherlands.

2:00 PM *KK10.2

Biomineral Ultrastructure. Pupa Gilbert¹, Rebecca A Metzler¹, Christopher E Killian¹, Susan N Coppersmith¹, Yurong Ma², Yael Politi², Steve Weiner² and Lia Addadi²; ¹Physics, University of Wisconsin, Madison, Wisconsin; ²Weizmann Institute of Science, Rehovot, Israel.

2:30 PM KK10.3

Quantitative X-ray Microtomography to Establish Structure-Property Linkages in Hybrid Materials Philipp Hunger¹, Amalie E Oroho¹, Adrian P Sheppard², Peter Cloetens³ and Ulrike Gesa K. Wegst¹; ¹Materials Science and Engineering, Drexel University, Philadelphia, Pennsylvania; ²Applied Mathematics, The Australian National University, Canberra, Australian Capital Territory, Australia; ³European Synchrotron Research Facility, Grenoble, France.

2:45 PM KK10.4

Collagen Fibril Orientation Mapping of Mineralized Tissue by Polarized Raman Spectroscopy. Admir Masic¹, John W Dunlop¹, Markus A Hartmann¹, Jong Seto¹, Sonja Gamsjäger², Paul Zaslansky¹ and Peter Fratzl¹; ¹Department of Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Germany; ²4th Medical Department, Ludwig Boltzmann Institute of Osteology at the Hanusch Hospital of WGKK and AUVA Trauma Centre Meidling, Vienna, Austria.

3:00 PM BREAK

3:30 PM *KK10.5

Quantitative Mechanical/Chemical Imaging of Bone from Dmp1 Null Mice. Xiaomei Yao, Lynda Bonewald, J David Eick and

Yong Wang; University of Missouri Kansas City School of Dentistry, Kansas City, Missouri.

4:00 PM *KK10.6

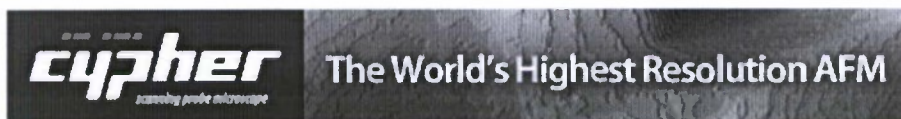
Probing the Molecular-level Structure of Biominerals. Melinda J Duer¹, David G Reid¹, Erica R Wise¹, Serena M Best², David Zou², Christian Jaeger³, Catherine M Shanahan⁴ and Michael Schoppert⁵; ¹Chemistry, University of Cambridge, Cambridge, United Kingdom; ²Materials, University of Cambridge, Cambridge, United Kingdom; ³Federal Institute for Materials Research and Testing, Berlin, Germany; ⁴Cardiovascular Division, Kings College London, London, United Kingdom; ⁵Internal Medicine and Cardiology, Philipps University, Marburg, Germany.

4:30 PM KK10.7

Compressive Failure of Human Trabecular Bone Studied by X-ray Microtomography. Farhat Ahmed^{1,2}, Graham R Davis² and Andy J Bushby¹; ¹Centre of Materials Research, Queen Mary University of London, London, United Kingdom; ²Dental Biophysics, Queen Mary University of London, London, United Kingdom.

4:45 PM KK10.8

Transmission X-ray Microscopy of the Nanostructure of Bone Trabeculae. Joy Andrews¹, Eduardo Almeida², Josh Alwood³, Marjolein van der Meulen⁴, Jie Chen⁵ and Piero Pianetta^{1,3}; ¹SSRL, SLAC, Menlo Park, California; ²NASA Ames Res Ctr, Moffett Field, California; ³Stanford University, Stanford, California; ⁴Mechanical & Aerospace Eng, Cornell University, Ithaca, New York; ⁵IHEP, Beijing, China.



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